



Description

GLOBAL ELECTRONIC TRADING SYSTEM

Inventors

Arman Glodjo, Nathan D. Bronson, and Scott E. Harrington

Related Applications

This application is related to and claims priority upon U.S. provisional patent application serial number 60/249,796 filed November 17, 2000 and U.S. provisional patent application serial number 60/288,310 filed May 2, 2001, which two provisional patent applications are hereby incorporated by reference in their entireties into the present patent application.

Technical Field

This invention pertains to the field of global electronic trading of commodities and financial instruments.

Background Art

Wright, Ben, "Unlocking the C2C forex riddle", euromoney.com, July 25, 2001, U.K., provides a general discussion of some of the business aspects of the present invention.

Morris, Jennifer, "Forex goes into future shock", Euromoney, October 2001, gives a general description of several computerized foreign exchange platforms, including one described in the present patent application.

1 Ahuja, R.K., Magnanti, T.L., and Orlin, J.B., Network
2 Flows; Theory, Algorithms, and Applications, Chapters 7 and 9
3 (Prentice-Hall, Inc. 1993), U.S.A., sets forth some algorithms
4 that may be useful in implementing the present invention.

5 U.S. patent 5,375,055 discloses a relatively simple
6 trading system that is capable of implementing only single-hop
7 trades. On the other hand, the present invention can
8 accommodate multi-hop trades. Further, in U.S. patent
9 5,375,055, the user is given information that suggests to him
10 that he can take a trade when he may not have enough credit to
11 take the whole trade. In the present invention, on the other
12 hand, if only part of a trade can be executed, that information
13 is given to the user; the user knows that he has enough credit
14 to execute at least the best bid and best offer that are
15 displayed on his computer.

16 An even simpler trading system is disclosed in European
17 patent application 0 411 748 A2 and in granted European patents
18 0 399 850 B1 and 0 407 026 B1, all three of which are assigned
19 to Reuters Limited. These Reuters documents describe a system
20 in which information concerning a potential trade is displayed
21 even if the user can't execute it at all. In the present
22 invention, such a potential trade would not be displayed at
23 all. Furthermore, the only credit limits that can be
24 accommodated in the Reuters system are volume limits for the
25 purposes of limiting settlement risk. In the present

1 invention, any agent may set credit limits in multiple ways so
2 as to limit not only settlement risk (measured both by
3 individual instrument volumes and by notional absolute values)
4 but also exposure risk. Furthermore, the Reuters keystations
5 require a human operator. In the present invention, on the
6 other hand, an API (application programming interface) enables
7 any participant to develop programs which partially or fully
8 automate the trading process.
9

10 Disclosure of Invention

11 Methods, systems, and computer readable media for
12 facilitating trading two items (L,Q) from the group of items
13 comprising commodities and financial instruments. At least two
14 agents (2) want to trade some instrument L at some price quoted
15 in terms of another instrument Q. The exchange of L and Q is
16 itself a financial instrument, which is referred to as a traded
17 instrument. A trading channel (3) between the two agents (2)
18 allows for the execution of trades. Associated with each
19 channel (3) are trading limits configured by the two agents (2)
20 in order to limit risk. A central computer (1) coupled to the
21 two agents (2) is adapted to convey to each agent (2) current
22 tradable prices and available volumes for the exchange of L for
23 Q and for the exchange of Q for L, taking into account the
24 channel (3) trading limits. The central computer (1)
25 facilitates trades that occur across a single trading channel
26
27
28

1 (3) and trades that require the utilization of multiple trading
2 channels (3).
3

4 Brief Description of the Drawings

5 These and other more detailed and specific objects and
6 features of the present invention are more fully disclosed in
7 the following specification, reference being had to the
8 accompanying drawings, in which:
9

10 Figure 1 is a block diagram illustrating a "type zero"
11 trading system embodiment of the present invention.

12 Figure 2 is a block diagram illustrating a "type 1"
13 trading system embodiment of the present invention.
14

15 Figure 3 is a block diagram illustrating a "type 2"
16 trading system embodiment of the present invention.

17 Figure 4 is a block diagram illustrating a "type 2" back-
18 to-back trade using the present invention.

19 Figure 5 is a block diagram illustrating an interlocking
20 network of type 1 and type 2 atomic units.

21 Figure 6 is a schematic diagram illustrating trading
22 limits for a traded instrument being traded between four agents
23 4,5 using three trading channels 3.
24

25 Figure 7 is a block diagram illustrating various ways that
26 agents 2 can be connected to enable them to use the present
27 invention.
28

1 Figure 8 is a timeline illustrating an embodiment of the
2 matching process used in the present invention.

3 Figures 9A and 9B are a block diagram illustrating an
4 embodiment of the border outpost process of the present
5 invention.

6 Figure 10 is a deal fulfillment graph.

7 Figure 11 is a flow diagram illustrating the sequence of
8 screen shots appearing on the computer of an agent 2 using the
9 present invention.
10

11 Figure 12 illustrates a log-in screen 21 of the computer
12 of an agent 2.

13 Figure 13 illustrates a custom limit order book overview
14 window 24 (multiple traded instruments).
15

16 Figure 14 illustrates a custom limit order book window 25
17 (single traded instrument).

18 Figure 15 illustrates a net exposure monitor 35.

19 Figure 16 illustrates a balance sheet window 36.

20 Figure 17 illustrates an open order overview and
21 management window 33.

22 Figure 18 illustrates a bid creation dialog box 28.

23 Figure 19 illustrates an offer creation dialog box 29.

24 Figure 20 illustrates a buy (immediate execution bid)
25 dialog box 30.
26

27 Figure 21 illustrates a sell (immediate execution offer)
28 dialog box 31.

1 Figure 22 is a flow diagram illustrating the computation
2 of a custom limit order book 24,25.

3 Figure 23 is a flow diagram illustrating the computation
4 of multi-hop flow limits for a single traded instrument among
5 all accounts.

6 Figure 24 is a flow diagram illustrating computation of a
7 directed graph of single-hop flow limits for a single traded
8 instrument among all accounts.

9 Figures 25A and 25B are a flow diagram illustrating
10 computation of minimum and maximum excursions for a single
11 account A and a single traded instrument.

12 Figure 26 is a flow diagram illustrating computation of a
13 position limit for a lot instrument L.

14 Figure 27 is a flow diagram illustrating computation of a
15 position limit for a quoted instrument Q.

16 Figure 28 is a flow diagram illustrating computation of a
17 volume limit for a lot instrument L.

18 Figure 29 is a flow diagram illustrating computation of a
19 volume limit for a quoted instrument Q.

20 Figure 30 is a flow diagram illustrating computation of a
21 notional position limit.

22 Figure 31 is a flow diagram illustrating computation of a
23 notional volume limit.

24 Figure 32 is a flow diagram illustrating computation of a
25 traded instrument L:Q position limit.

1 Figure 33 is a flow diagram illustrating computation of a
2 traded instrument L:Q volume limit.

3 Figure 34 is a flow diagram illustrating reporting by
4 computer 1 of a single-hop trade.

5 Figure 35 is a flow diagram illustrating reporting by
6 computer 1 of a multi-hop trade.

7
8 Detailed Description of the Preferred Embodiments

9 The present invention enables an arbitrary number of
10 agents 2 of arbitrary type (such as corporate treasuries, hedge
11 funds, mutual funds and other collective investment schemes,
12 banks and other financial institutions, and other institutions
13 or persons) to trade commodities and financial instrument pairs
14 directly amongst each other (thus facilitating client-to-
15 client, or C2C trading) by making orders to their peers to buy
16 and sell the traded instrument pairs over "credit atomic units"
17 and "credit molecules".

18
19 By way of example, the application highlighted most often
20 herein is the spot foreign exchange (spot FX) market, but it
21 must be understood that the present invention has applicability
22 to trading in any type of over-the-counter commodity or
23 financial instrument, including physical commodities, energy
24 products (oil, gas, electricity), insurance and reinsurance
25 products, debt instruments, other foreign exchange products
26 (swaps), and compound instruments and other derivatives
27 composed or derived from these instruments.
28

1 A trade is the exchange of a lot of instrument L for a
2 quoted instrument Q. The lot instrument L is traded in an
3 integral multiple of a fixed quantity referred to as the lot
4 size. The quoted instrument Q is traded in a quantity
5 determined by the quantity of the lot instrument L and the
6 price. The price is expressed as Q per L. In a spot FX trade,
7 the lot instrument L and the quoted instrument Q are implicit
8 contracts for delivery of a currency on the "spot" date
9 (typically two business days after the trade date).
10

11 In the present specification and claims, entities that
12 wish to trade with each other are referred to as "agents" 2.
13 Agents 2 that extend credit to other agents 2 are referred to
14 as credit-extending agents 5. Agents 2 that do not extend
15 credit to other agents 2 are referred to as clients 4 or non-
16 credit-extending agents 4.
17

18 Two agents 2 may have direct trading channels 3 between
19 them, where the trading channels 3 correspond to credit
20 extended from one credit-extending agent 5 (typically a bank,
21 financial institution, or any clearing entity) to the other
22 agent 2. Trading channels 3 are typically secured via
23 placement of collateral (margin) or other form of trust by an
24 agent 2 with the credit-extending agent 5. Typically, trading
25 channels 3 amongst credit-extending agents 5 and non-credit-
26 extending agents 4 already exist. In the spot FX market, these
27 trading channels 3 are referred to as trading accounts. In the
28

1 case that two credit-extending agents 5 have a trading channel
2 3 between them, only one agent 2 acts in a credit-extending
3 capacity with regards to that trading channel 3.

4 Credit-extending agents 5 that allow the central computer
5 1 to utilize a portion of their trading channels 3 to allow
6 other agents 2 to trade with each other are referred to as
7 "credit-bridging agents" 5. In a preferred implementation of
8 the present system, existing banks, financial institutions, and
9 clearing entities are credit-bridging agents 5 as well as
10 credit-extending agents 5; and existing trading customers of
11 those institutions 5 are clients 4.

13 Compared with prior art systems, the present invention
14 gives a relative advantage to clients 4 compared to credit-
15 extending agents 5, by enabling one-way or two-way orders from
16 any agent 2 to be instantly displayed to all subscribing agents
17 2, enabling a trade to take place at a better price, with high
18 likelihood, than the price available to clients 4 under prior
19 art systems. The present invention brings together clients 4
20 who may be naturally on opposing sides of a trade, without
21 conventional spreads historically charged to them 4 by credit-
22 extending agents 5 for their 5 service as middlemen. Of
23 course, credit-extending agents 5 also benefit on occasions
24 when they are natural sellers or buyers.

27 Unlike prior art systems, the present invention arranges
28 multi-hop deals to match orders between natural buyers and

1 sellers who need not have a direct trading relationship. For
2 the application to spot FX trading, a multi-hop deal can be
3 realized through real or virtual back-to-back trades by one or
4 more credit-bridging agents 5. In terms of the underlying
5 transfers of financial instruments, a multi-hop deal is similar
6 to the existing practice of trade "give-ups" from one broker to
7 another.
8

9 Unlike prior art systems, the present invention computes
10 trading limits from not only cumulative volume but also from
11 net position limits, where both volume and position limits may
12 be set in terms of the traded instrument (instrument L for
13 instrument Q), in terms of any underlying instruments to be
14 exchanged (delivered) upon settlement (such as L individually,
15 Q individually, or other instruments), or in terms of the
16 notional valuations of such instruments. This allows all
17 agents 2, especially credit-bridging agents 5, to control risk
18 far more flexibly. Limiting traded or delivered instruments'
19 cumulative volume helps to manage settlement risk. Limiting a
20 traded instrument's net position (net L:Q position) helps to
21 manage market risk. Limiting a delivered underlying
22 instrument's net position (total net L, total net Q, or some
23 other underlying instrument's position) helps manage market and
24 credit risk by reflecting the ultimate effect of any trade on
25 any account's future balance sheet. The cumulative volume
26
27
28

1 limits allowed by prior art systems are able to address only
2 settlement risk concerns.

3 The present invention has a natural symmetry; in the
4 preferred implementation, not only are credit-bridging agents 5
5 (financial institutions) able to operate as market makers and
6 post one-way (just a bid or ask) and two-way (both bid and ask)
7 prices to agents 2, but clients 4 may post one-way and two-way
8 prices to credit-bridging agents 5 and other clients 4 of any
9 other credit extending or credit bridging agent 5. This
10 symmetry is not present in prior art trading systems.

11
12 The present invention uses a central computer 1 to
13 calculate trading limits, to prepare custom limit order books
14 24,25, and to match orders, but all post-trade bookkeeping and
15 settlement is handled in a de-centralized manner by the
16 counterparties 2 involved in each trade. The central computer
17 1 is a network of at least one physical computer acting in a
18 closely coordinated fashion.

19
20 Every agent 2 subscribing to a system employing the
21 present invention can be thought of as a node 2 in an
22 undirected graph (Figs. 1-5, 10). The undirected edges 3 of
23 such graphs indicate the existence of a trading channel 3
24 (account) between two nodes 2, typically an arrangement of
25 trading privileges and limits based on the extension of credit
26 from one node 2 to another 2 and likely backed by collateral
27 placed by one node 2 with the other 2. Some nodes 5 in the
28

1 graph, corresponding to credit-bridging agents 5, allow credit
2 to be bridged, while other nodes 4 are clients 4 who
3 permanently or temporarily forbid credit bridging. For the
4 application to spot FX trading, a credit-bridging agent 5
5 authorizes the central computer 1 to initiate back-to-back spot
6 trades, where simultaneous trades in opposite directions at the
7 same price are made between the credit bridging agent 5 and two
8 or more different agents 2, such that the net position effect
9 to the credit bridging agent 5 is exactly zero.

11 For each trading channel (account) 3, the central computer
12 1 maintains a set of limits set by the credit-extending agent 5
13 and a set of limits set by the non-credit-extending agent 2.
14 Either of these sets of limits may be empty. These limits
15 specify maximums of cumulative volume of each traded instrument
16 L:Q, maximum cumulative volume of an underlying instrument
17 (e.g. L, Q, or other), maximum cumulative notional value (e.g.
18 U.S. dollar equivalent), maximum positive or negative net
19 position of each traded instrument L:Q, maximum positive or
20 negative net position of the underlying instrument (e.g. L, Q,
21 or other), and maximum absolute net notional position (e.g.,
22 U.S. dollar equivalent) value total.

25 For each trading channel (account) 3, the central computer
26 1 maintains information sufficient to compute the current value
27 of all the quantities upon which limits may be placed. The
28 cumulative volume values are reset to zero with some period,

1 typically one business day, at such a time as is agreeable to
2 both agents. It is illustrative to note that the cumulative
3 volume values always increase toward their limit with each
4 trade, while the net position values may be decreased back to
5 zero or near zero and may change in sign.
6

7 An agent 2 may add, remove, or adjust any of the elements
8 of the set of limits specified by that agent 2 at any time.

9 Since trading is permitted or denied based on these limit-
10 related values, the central computer 1 provides a way for the
11 agents 2 that are parties to an account to inform the central
12 computer 1 of any external activity that would affect these
13 values, such as odd-lot trades and trades made through existing
14 trading devices, or to simply reset all limit-related values to
15 a predefined state.
16

17 Based on the current values of all these limit-related
18 quantities, the central computer 1 computes for each traded
19 instrument L:Q a directed graph (Figure 6) of maximum
20 excursions. In the directed graph for each traded instrument
21 L:Q, each directed edge 3 from a node 2 to another node 2 has a
22 value that indicates, based on the current position, how many
23 of the traded instrument L:Q may be bought by the first node 2
24 from the second node 2. There are typically directed edges 3
25 in both directions between any pair of nodes 2, since the
26 instrument L:Q may be bought or sold. The trading limit values
27 (maximum excursions) of these buying and selling edges 3
28

1 between two nodes 2 vary from moment to moment as trades are
2 made and/or credit limits are adjusted by either node 2.

3 For all traded instruments L:Q and for all nodes 2 that
4 trade L:Q and for all other nodes 2 that trade L:Q, the central
5 computer 1 uses the directed graph of maximum excursions (Fig.
6 7) to compute the maximum flow from the first node 2 to the
7 second node 2. Note that this means that each pair of nodes 2
8 that trade L:Q will have the maximum flow between them 2
9 calculated in both directions.
10

11 The prior art systems could be simulated by the present
12 invention by first eliminating the ability of any node 2 to be
13 a credit-bridging agent 5 so that the "single-pair maximum
14 flow" is merely the flow enabled by directed edges 3 connecting
15 the pair of nodes 2 directly. Second, all trading limits by
16 non-credit-extending agents 4 would be disabled and only
17 cumulative volume limits on underlying instruments would be
18 allowed for credit-extending agents 5, corresponding to limits
19 only on settlement risk.
20

21 For purposes of illustrating the present invention,
22 consider, for example, an agent A extending credit to agent B
23 for the purposes of trading spot FX using the present
24 invention, and between the U.S. dollar (USD), Euro (EUR), and
25 Japanese Yen (JPY) in particular. Suppose agent B buys 1 lot
26 of EUR:USD at 0.9250, then sells 1 lot of EUR:JPY at 110.25,
27 with both trades having agent A as counterparty 2. The first
28

1 trade will upon settlement result in 1,000,000 EUR received by
2 agent B and 925,000 USD paid by agent B, while the second trade
3 will result in 1,000,000 EUR paid by agent B and 110,250,000
4 JPY received by agent B. From the perspective of agent B, the
5 account stands +1M EUR toward the EUR:USD cumulative volume
6 limit, +1M EUR toward the EUR:USD net position limit, +1M EUR
7 toward the EUR:JPY cumulative volume limit, -1M EUR toward the
8 EUR:JPY net position limit, +2M EUR toward the EUR cumulative
9 volume limit, +925,000 USD toward the USD cumulative volume
10 limit, +110,250,000 JPY toward the JPY cumulative volume limit,
11 ZERO with respect to the EUR net position limit, -925,000 USD
12 toward the USD net position limit, and +110,250,000 JPY toward
13 the JPY net position limit. Further supposing that the
14 instrument valuations in agent B's home currency of USD are
15 0.9200 EUR:USD and 0.009090 JPY:USD, then the account stands
16 $(2M \times 0.9200 + 925,000 + 110,250,000 \times 0.009090 =)$ 3,767,172.50
17 USD toward the notional USD cumulative volume limit (useful for
18 limiting settlement risk), and $(0 \times 0.9200 + 925,000 +$
19 $110,250,000 \times 0.009090 =)$ 1,927,172.34 USD toward the absolute
20 notional net position total.

21
22
23 Now suppose agent B buys 1 lot of USD:JPY at 121.50, which
24 upon settlement will result in 1,000,000 USD received and
25 121,500,000 JPY paid. The net single-instrument positions are
26 now 0 EUR, 75,000 USD, and -10,250,000 JPY. Rather than
27 delivering JPY at settlement (which will entail carrying a JPY
28

1 debit balance in the account), agent B will probably choose to
2 arrange an odd-lot deal with agent A to buy 10,250,000 JPY at a
3 rate of, for instance, 121.40 USD:JPY, at a cost of 84,431.63
4 USD, resulting in final account position values of 0 EUR, -
5 9,431.63 USD, and 0 JPY. In other words, agent B has lost
6 9,431.63 USD in its account with agent A once all the
7 settlements occur.
8

9 Alternatively, agent B may choose to "roll forward" any
10 EUR or JPY net position from the spot date to the next value
11 date, or to any forward date by buying or selling an
12 appropriate FX swap instrument from or to agent A.
13

14 Odd-lot spot, odd-lot forward, odd-lot swap, and deals
15 with a specific counterparty 2 are not amenable to trading via
16 the "limit-order book" matching system, but instead may be
17 facilitated by the central computer 1 through a request-for-
18 quote mechanism. Since the central computer 1 knows the net
19 positions of all the accounts, it may further recommend such
20 deals on a periodic basis, such as a particular time that both
21 agents 2 consider to be the end of the business day for the
22 account in question.
23

24 For the application of the present invention to markets
25 other than spot FX, triangular interactions between traded
26 instrument pairs are not as much a concern. The limits set by
27 credit-extending agents 5 are handled the same way, where the
28 limits on commodity holdings or currency payments are

1 translated by the central computer 1 into excursion limits (how
2 many lots an agent 2 may buy or sell) in real-time.

3 The present invention can be implemented in a combination
4 of hardware, firmware, and/or software. The software can be
5 written in any computer language, such as C, C++, Java, etc.,
6 or in a combination of computer languages. The hardware,
7 firmware, and software provide three levels of content: a)
8 trade screens, b) post-trade content for back offices and
9 clearing units, and c) real-time credit management content.
10 Through an API (application programming interface) 38, agents 2
11 can securely monitor and change in real time the credit limits
12 they have specified for each trading channel 3 in which they
13 participate. (Note that the maximum flow across a trading
14 channel 3 is the minimum of the trading limits specified by the
15 two agents 2 associated with the channel 3, so a non-credit-
16 extending agent 4 can only further reduce the credit limits
17 assigned by the credit-extending agent 5.)

20 The link between the agents 2 and the central computer 1
21 can be any telecommunications link--wired, wireless, Internet,
22 private, etc. Computer 1 can be located anywhere in the world.
23 It can be mirrored for purposes of data backup, to increase
24 throughput, or for other reasons; in that case, there is a
25 second central computer 1(2). The backup central computer 1(2)
26 is a network of at least one physical computer operating in a
27 closely coordinated fashion. Such a backup computer 1(2) is
28

1 shown in Figure 7, and insures that there will be no
2 interruption of service with hardware, software, or network 6,7
3 failures (neither during the failure nor during the needed
4 repairs); and further insures that the present invention has
5 the ability to recover from a disaster event.
6

7 Since the present invention operates on a global scale,
8 said operation has to satisfy local laws and regulations to
9 enable the services of the present invention to be provided.
10 The present invention is therefore designed to enable such
11 accommodations to be made.

12 The present invention supports purpose-specific "atomic
13 units" enabling trading between specific types of agents 2.
14 The basic atomic units are "type 0", "type 1", and "type 2",
15 where a "type 0 unit" involves a single pair of agents 2 where
16 one extends credit to the other, a "type 1 unit" involves a
17 single client 4 trading with a collection of credit-extending
18 agents 5, and a "type 2 unit" involves a single credit-bridging
19 agent 5 enabling a collection of its clients 4 to trade with
20 itself 5 and with each other 4.
21

22 Figure 1 illustrates the simplest atomic unit, type 0. A
23 first agent 2(1) and a second agent 2(2) wish to trade at any
24 given time some number of round lots of instrument L in
25 exchange for a quantity of another item Q, which we refer to as
26 the quoted instrument or quoted currency. A trading channel 3
27 (account) between the two agents 2 allows for the execution of
28

1 the trades and settlement of the underlying instruments.
2 Inherent in the trading channel 3 are flow limits (trading
3 limits) on the items L,Q being traded and limits on any
4 underlying instruments exchanged upon settlement of the L,Q
5 trade. A central computer 1, under control of the operator or
6 owner of the system, is coupled to the two agents 2. The
7 computer 1 is adapted to convey to each agent 2 current bid
8 orders and offer orders originating from the other
9 participating agent 2. The current set of tradable bid and
10 offered prices and sizes is constrained by the trading
11 channel's trading limits, and is preferably conveyed in the
12 form of a custom limit order book 24,25 for each agent 2, as
13 will be more fully described below. The custom limit order
14 book 24, 25 is a chart, typically displayed on the agent's
15 computer, of a preselected number of bids and offers for the
16 instrument pair L,Q in order of price, and within price, by
17 date and time (oldest first).

20 Typically, but not necessarily, each agent 2 is coupled to
21 the central computer 1 when the agents 2 are trading. The
22 identification of one of the two agents 2 as the "credit-
23 extending agent 5" is necessary only for the creation of a
24 trading channel 3, since either agent 2 may post orders (making
25 the market) in the same way.

27 Figure 2 illustrates the type 1 atomic unit: a client
28 agent 4 is looking to trade with several credit-extending

1 agents 5 with whom it 4 has a credit relationship. Note that
2 because each credit-extending agent 5 participates in only a
3 single trading channel 3 (with which the central computer 1 is
4 aware), there is no opportunity for the credit-extending agents
5 to act as credit-bridging agents 5. The type 1 scenario
6 involves the client 4 placing a one-way or a two-way order via
7 computer 1. Computer 1 insures that every institution 5 with
8 which the client 4 has a credit relationship sees the order
9 instantaneously. If none of the institutions 5 wish to deal at
10 the client's current price, they 5 may post their own counter-
11 offers that then appear on the client's custom limit order book
12 24,25, but not on those of the other institutions 5. The
13 client 4 may then choose to modify or cancel its 4 order to
14 deal at the best price possible, while the institutions 5
15 benefit by seeing this client's 4 possible interest in buying
16 or selling.

19 The institutions 5 may also supply via computer 1 tradable
20 bid and offered prices to the client 4 that will not be seen by
21 the other institutions 5.

22 The solid lines in Figure 2 represent credit relationships
23 between client 4 and credit-extending agents 5. The credit-
24 extending agents 5 may have credit relationships outside the
25 scope of the present invention, but only those trading channels
26 3 whose credit limits are maintained by the central computer 1
27 are illustrated or discussed. The dashed lines in Figure 2
28

1 represent communication links between the agents (4,5) and the
2 central computer 1.

3 As a sub-species of type 1, there can be multiple clients
4 4, as long as all such clients 4 have credit relationships with
5 the same credit-extending agents 5, and the clients 4 are not
6 allowed to trade with each other 4.
7

8 Computer 1 provides several post-trade capabilities to the
9 client 4 and to the financial institution's 5 trading desk as
10 well as to its 5 back office and credit desk, all in real-time.

11 The clearing of the trade is done by conventional means.
12 The operator of computer 1, though it could, does not need to
13 act as a clearing agent and does not need to hold as collateral
14 or in trust any financial or other instruments. The client 4
15 can direct that all clearing is to be handled by a certain
16 credit-extending agent 5. The clearing procedures are
17 dependent upon the instruments traded and any netting
18 agreements or special commodity delivery procedures required
19 for those instruments.
20

21 The type 2 atomic unit is illustrated in Figure 3. Type 2
22 enables client 4 to client 4 dealing among the clients 4 of a
23 particular credit-bridging agent 5, as well as enabling client
24 4 to credit-extending agent 5 trading. As usual, the anonymous
25 order-matching process is triggered whenever an order to buy is
26 made at a price equal to or higher than the lowest outstanding
27 offer to sell, or vice versa. If the match is between a client
28

1 4 and the credit-bridging agent 5, then a single deal is booked
2 between those two parties 2. However, if the match is between
3 two clients 4, then two back-to-back deals are booked, one
4 between the seller client 4 and the credit-bridging agent 5,
5 and the other between the buyer client 4 and the credit-
6 bridging agent 5. This is akin to creating virtual trading
7 channels between the clients 4. A client 4 who has a credit
8 relationship with the credit-bridging agent 5 is able to post
9 its one-way or two-way order via computer 1, which causes the
10 order to be instantly displayed to all other clients 4 and to
11 the credit-bridging agent 5 itself if the existing credit
12 limits between the posting client 4, the credit-bridging agent
13 5, and the receiving client 4 would allow a portion of the
14 order to be executed.
15
16

17 This "mini-exchange" has the liquidity of the natural
18 supply and demand of the entire client 5 base, combined with
19 the market-making liquidity that the credit-bridging agent 5
20 would be supplying to its clients 4 ordinarily. It is
21 certainly expected, and beneficial to the overall liquidity,
22 that the credit-bridging agent 5 will be able to realize
23 arbitrage profits between the prices posted by its clients 4
24 and the prices available to the credit-bridging agent 5 through
25 other sources of liquidity. In fact, there may be instances in
26 some markets where clients 4 are also able to arbitrage against
27 other trading systems.
28

1 Again, computer 1 provides several post-trade capabilities
2 to the client 4 and to the trading desk, the back office, and
3 the credit desk of the credit-bridging agent 5, all in real-
4 time, as in type 1.

5 A pair of back-to-back trades is illustrated in Figure 4,
6 showing that agents 4(2) and 4(4) are the ultimate buyer and
7 seller of the deal, but they each deal only with the credit-
8 bridging agent 5 as their immediate counterparty 2.

10 As with all the various atomic units, central computer 1
11 updates the current tradable information after each trade, and
12 causes this information to be displayed on the computers
13 associated with all of the subscriber agents 2.

15 Again, computer 1 provides several post-trade capabilities
16 to the clients 4, as well as to the credit-bridging agent's 5
17 trading desk, its 5 back office, and its 5 credit desk, all in
18 real-time. The credit-bridging agent 5 acts as a clearing
19 agent for this trade, and is able to monitor the client-to-
20 client exposure, in real time.

21 Thus is created a price-discovery mechanism for end-users
22 2 with direct transparency between entities 2 wishing to take
23 opposite sides in the market for a particular instrument. The
24 present invention encompasses decentralized operation of an
25 arbitrary number of separate, type-1 and type-2 atomic units.
26 Efficient price discovery is provided to the end user 2 in a
27 decentralized liquidity rich auction environment, leveraging
28

1 existing relationships, and co-existing with and indeed
2 benefiting from traditional trading methodologies.

3 Furthermore, an arbitrary number of different type 0, type
4 1, and type 2 atomic units may be interconnected, bottom-up, as
5 illustrated in Fig. 5, to provide, at all times, a liquidity
6 rich efficient price-discovery mechanism to the subscribing
7 agents 2, enabling more and more agents 2, across different
8 atomic types, to conduct efficient direct auctions with each
9 other directly. The various atomic units may be interconnected
10 into a molecular credit-network.

12 In Figure 5, which may be considered to illustrate a "type
13 3" scenario, shaded circles represent credit-bridging agents 5
14 and un-shaded circles represent clients 4.

16 For purposes of simplicity, central computer 1 is not
17 shown on Fig. 5, but is in fact coupled to all nodes 2. Each
18 node 2 has proprietary client software on a computer associated
19 with said node 2, enabling said node 2 to communicate with
20 central computer 1. Such software may take the form of a Web
21 browser. The diameters of the arrow-headed lines 3 represent
22 instrument excursion limits deduced from each trading channel's
23 various types of credit limits. A "shortest weighted paths"
24 algorithm or other minimum cost flow algorithm is used to
25 calculate the minimal path between two agents 2 subject to
26 credit flows to enable a trade between the agents 2. The
27 trading agents 2 may be arbitrarily removed from one another,
28

1 both in geographic terms as well as by type of business
2 activity in which they 2 are involved.

3 Each connected piece of Fig. 5 maintains full transparency
4 of orders posted on computer 1 to all financial institutions 5
5 and clients 4 who are on any unexhausted credit path 3 to the
6 posting entity 2. Each of the entities 2 who are able to see
7 the posted order are in effect competing, through the reverse
8 auction, for that particular deal, enabling further efficient
9 price-discovery to the posting entity 2.
10

11 Prior to each trade, computer 1 internally computes the
12 values that define one of these Figure 5 graphs for each pair
13 of instruments being traded. From the graph, computer 1
14 creates a table of multi-hop trading limits showing the trading
15 limits between each pair of nodes 2. From the table of multi-
16 hop trading limits, computer 1 prepares a custom limit order
17 book 24,25 for each node 2 for each traded instrument pair.
18 After every trade, computer 1 recalculates the trading limits
19 3, thus leading to a new graph (Figure 5) for that instrument
20 pair. Recalculating the trading limits 3 for a given traded
21 instrument pair can affect the topology (trading limits 3) of
22 other graphs (Figure 5) for other traded instrument pairs.
23 This can occur, for example, when the trading limits are
24 notional trading limits.
25

26 On Figure 5, if an agent 2 has imposed its own internal
27 limits that are smaller than the trading limits that have been
28

1 imposed by a credit-extending agent 5 that is extending it 2
2 credit, computer 1 uses the smaller of the two limits when it
3 creates Figure 5.

4 Each trading channel 3 represents an account between a
5 credit-extending agent and a client agent 4. In the preferred
6 implementation of this invention, all credit-extending agents
7 are credit-bridging agents 5. Even when two adjacent nodes 2
8 are fully qualified to be credit-extending agents 5, one acts
9 as the credit-extending agent 5 in the transaction and the
10 other acts as the client agent 4 in the transaction. The
11 accounts that exist between credit-extending agents 5 and
12 client agents 4 comprise specified input credit limits, balance
13 holdings, and collateral; computer 1 calculates trading limits
14 from this information.

15
16
17 The operator of computer 1 typically has, in its standard
18 agreement with a subscribing agent 2, language stating that if
19 the agent 2 has entered into a written subscription agreement
20 with the operator of computer 1 and said agent 2 trades outside
21 of the network 6,7 operated by the operator of computer 1, that
22 agent 2 is obligated to notify the operator of computer 1 about
23 such outside trades, so that computer 1 can recalculate the
24 trading limits as necessary.

25
26 Figure 5 can be thought of as an n-hop credit network,
27 where n is an arbitrary positive integer. In any transaction,
28 the instrument flow can fan out from one source node 2 and then

1 collapse to the destination node 2; the instrument flow does
2 not have to stay together as it flows from the source 2 to the
3 destination 2. See Fig. 10 for an example of this phenomenon.
4 In calculating the maximum capacity of the network 6,7,
5 computer 1 uses a maximum flow algorithm such as one described
6 in chapter 7 of the Ahuja reference cited previously. In
7 determining the actual flow used to complete the trade,
8 computer 1 uses a minimum cost flow algorithm such as one
9 described in chapter 9 of said Ahuja reference, where the cost
10 to be minimized is a function of the actual cost to execute the
11 trade and other factors, such as projected settlement costs,
12 flow balancing heuristics, and a randomizing component.
13

14 The network 6,7 of Figure 5 is a non-disjointed network.
15 By that is meant that every node 2 in the network 6,7 is
16 coupled to at least one other node 2, and at least one of the
17 agents 2 associated with each trading channel 3 is a credit-
18 bridging agent 5. The individual trading limits 3 that
19 computer 1 computes for each agent 2 pair are dependent upon
20 the topology of the network 6,7. Computer 1 essentially
21 transforms the network 6,7 into a virtually cliqued networked.
22 A "cliqued network" is one in which every node 2 is connected
23 to every other node 2. A "virtually cliqued network" is one in
24 which every node 2 has a capability to trade with every other
25 node 2, but not necessarily directly. In order to preserve the
26 desired feature of anonymity, each node 2 knows the identities
27
28

1 of only its immediate trading partners 2, and does not
2 necessarily know whom 2 it is actually trading with.

3 As a trading system that leverages the existing
4 relationships in the market for the traded instrument, the
5 present invention provides all market players 2 (typically
6 banks, financial institutions, clearing entities, hedge funds,
7 and any corporations or other entities) the ability to trade
8 directly with each other through a custom limit order book
9 24,25. These agents 2 may already be connected together with
10 credit relationships, but prior art systems allow trading only
11 between two parties that have an explicit credit arrangement.
12 The present invention analyzes the credit-worthiness of a
13 potential counterparty 2 at a higher level, performing this
14 analysis in real time, and providing each party 2 with a limit
15 order book 24,25 customized to its 2 current credit
16 availability.

17 For example, in Figure 6 we consider a small network of
18 foreign exchange players: banks 5(B) and 5(C), which have a
19 credit relationship with each other, and clients 4(A) and 4(D),
20 who have margin placed with banks 5(B) and 5(C), respectively
21 (we leave the margin currency and traded instrument
22 unspecified). The specified input credit limits are specified
23 as traded instrument L:Q credit limits (just one way of
24 specifying input credit limits out of eight possible ways
25 enumerated in the present patent application). Client 4(A)'s
26
27
28

margin allows it to trade +/- 10M with 5(B), 5(B)'s relationship allows it to trade +/- 50M with 5(C), and 5(D)'s margin allows it to trade +/- 5M with 5(C). This information is supplied to computer 1, which draws Figure 6 from said information.

Figure 6 illustrates a simplified type 3 network in which there are two client agents 4 and two credit-extending agents 5 which are also credit-bridging agents 5. Figure 6 also illustrates the trading limits between each pair of coupled agents 4,5. Table 1 shows the maximum multi-hop credit limits that are then calculated by computer 1 for the simplified network of Figure 6 as follows:

Table 1:

	A	B	C	D
A	infinity	10M	10M	5M
B	10M	infinity	50M	5M
C	10M	50M	infinity	5M
D	5M	5M	5M	infinity

Computer 1 then uses the information contained in Table 1 to create a custom limit order book 24,25 for each agent A, B, C, D, and causes the custom limit order book 24,25 to be displayed on the computer screen of the respective agent A, B,

1 C, D. The filtered bids and offers in the custom limit order
2 book 24,25 are for volumes that are an integral multiple of the
3 lot size even if the computed Table 1 amounts contain values
4 which are not integral multiples of the lot size, with non-
5 integral multiples rounded toward 0.

6
7 If client A posts a bid for 10M, computer 1 causes the
8 full bid to appear on the custom limit order books 24,25 of
9 banks B and C, and computer 1 causes a filtered bid for 5M to
10 appear on the custom limit order book 24,25 of client D,
11 because the maximum credit (implicit or explicit) available
12 between A and D is +/- \$5M. If there is no implicit or explicit
13 credit available between two nodes 2, they 2 are not allowed to
14 see each other's bids and offers at all on their custom limit
15 order books 24,25.

16
17 The network 6,7 of the present invention is preferably
18 built using the Internet Protocol (IP) (because of its
19 ubiquity), and may reside on the Internet itself or other
20 public IP network 7 (Fig. 7).

21
22 It is also possible to locate part or all of the network
23 6,7 on a private fiber backbone 6, so that information bound
24 for the Internet 7 can traverse most of the distance to its
25 destination on the presumably higher speed private network 6.
26 The slower public Internet 7 is then used for just the last
27 segment of travel. It is also possible to provide clients 2
28 with dedicated bandwidth through private IP networks 6 in order

1 to provide additional levels of quality and service. A single
2 dedicated connection 6 may be backed up by an Internet
3 connection 7, or multiple private connections 6 can be used to
4 avoid the public network 7 entirely.

5 On Figure 7, the three illustrated agents 2 can be three
6 separate companies, three computers within the same company, or
7 a hybrid of the above.

8 The network 6,7 interfaces with both people and automated
9 systems (computers), so it provides three access methods:

- 11 • human -- Graphical User Interface (standalone or browser-
12 based application) for trading, interactive queries, and
13 account management;
- 14 • human/computer -- HTTP reports interface (HTML, XML, PDF,
15 or Excel) for queries only;
- 16 • computer -- Application Programming Interface 38
17 (available in Java and COBRA with bridges to FIX, JMS,
18 SOAP, and ebXML) for trading, queries, and account
19 management.
20 management.

21 An agent's 2 software can be launched from the agent's 2
22 browser but run as a standalone application for better
23 performance and stability.

24 The computer of each agent 2 can have associated therewith
25 an application programming interface (API) 38. The API 38 is a
26 standard interface exposed by the central computer 1 that
27 enables the user 2 to write customized instructions enabling
28

1 two-way communication between central computer 1 and the user
2 2. In the case where the user 2 is a credit extending agent 5,
3 the API 38 can be used to update the agent's backoffice
4 information. The agent 2 can program his API 38 to make and
5 cancel orders (bids and/or offers). The agent 2 can use his
6 API 38 to receive and reformat custom limit order books 24,25
7 for any instruments. The agent 2 can use his API 38 to set
8 trading limits, with the understanding that the actual trading
9 limits are the minimum of the trading limits specified by the
10 two agents 4,5 associated with an account. The API 38 can be
11 programmed to estimate how much it would cost an agent 2 to
12 liquidate his position in an instrument. The API 38 can be
13 programmed to estimate that agent's profit/loss amount for each
14 instrument being traded; this information can be combined with
15 the agent's custom limit order book 24, 25. Anything that can
16 be achieved by the GUI (graphical user interface) (Figs. 12-21)
17 can be achieved via the API 38.

20 Any and all features of the API 38 can be programmed to
21 operate automatically, including automatic bidding, offering,
22 buying, and selling. Automated processes accessing computer 1
23 via application programming interface 38 or a bridge use the
24 same cryptographic protocols as for a human agent 2 inputting
25 instructions via his computer's GUI. Whether an API 38 or a
26 GUI is used, an agent's private key for computerized access to
27
28

1 computer 1 can be stored in the agent's computer, provided said
2 computer has sufficient security safeguards.

3 Privacy, authentication, and non-repudiation are achieved
4 in the present invention via the use of cryptography in a
5 variety of different forms. The cryptographic techniques can
6 comprise symmetric key and/or asymmetric key (public key)
7 cryptography. All data streams are encrypted, e.g., by using
8 SSL (Secure Socket Layer) connections or a combination of SSL
9 encryption with additional authentication and encryption.
10 Authentication can be required between computer 1 and an agent
11 2 at any and all times these devices 1,2 communicate with each
12 other. This authentication can be achieved through the use of
13 digital certificates. Revalidation of credentials can be
14 required at the time a trade is consummated.

15 Each agent 2 may store its private key on a tamper-
16 resistant hardware device such as a smartcard, protected by a
17 password. The combination of a physical token (the card) with
18 a logical token (the password) ensures two levels of security.
19 The hardware token may contain a small CPU that allows it to
20 perform the necessary cryptographic operations internally, so
21 that the agent's private key never leaves the smartcard. In a
22 preferred embodiment, computer 1 handles bulk
23 encryption/decryption using symmetric key cryptography after
24 the slower public key cryptography has been used to exchange a
25 session key between agent 2 and computer 1.

1 While trading in the present invention is peer-to-peer,
2 order matching for any particular instrument is done at a
3 centralized location 1 to maintain transactional integrity.
4 Figure 8 illustrates the order matching process. In step 8,
5 the first agent 2(1) places a bid via its software to computer
6 1, which accepts the bid at step 9. Computer 1 then calculates
7 changes to the custom limit order books 24,25 of agents 2(1)
8 and 2(2) at steps 10 and 11, respectively, taking into account
9 appropriate trading limits 3. At step 12, the second agent
10 2(2) takes the bid. Step 12 occurs right before step 13, in
11 which a third agent 2(3) (not illustrated) posts a new offer
12 (bid or offer) for the traded instrument L:Q. At step 14,
13 computer 1 makes the match between the first agent 2(1) and the
14 second agent 2(2).
15
16

17 Reporting of the trade is described below in conjunction
18 with Figs. 35 and 36.

19 A network 6,7 implementing the present invention can span
20 the entire world, which means that there may be time
21 differences for a message sent by different agents 2 to
22 computer 1. Assuming a network 6,7 that sends signals at the
23 speed of light but that cannot transmit through the Earth, a
24 message sent to the other side of the Earth would have a round-
25 trip time of at least 130 milliseconds. On existing IP
26 networks, it is observed that if the central computer 1 were
27 located in New York, the maximum average round-trip
28

1 communication time between the central computer 1 and a
2 computer in any of the major financial centers is less than 300
3 milliseconds.

4 We want to ensure that all agents 2 have a level playing
5 field in accessing computer 1, regardless of where these agents
6 2 are situated around the world. Determining the latency for
7 each agent 2 and then introducing an individual delay on an
8 agent-by-agent basis to try to equalize time-of-arrival at
9 computer 1 would be very difficult (due to short term
10 fluctuations in network 6,7 lag), and could have the undesired
11 effect of overcompensating. A malicious agent 2 could also
12 falsify its network 6,7 delay, unfairly obtaining early access
13 to computer 1.

14 In order to compensate for the various time lags in
15 sending messages between agents 2 and computer 1 on a global
16 basis, the present invention transmits information as rapidly
17 as possible while flagging the order of messages to compensate
18 for latency. The flagging is done by means of border outpost
19 computers 16 (Figure 9).

20 For agents 2 remote from computer 1, a border outpost
21 computer 16 is inserted into the network 6,7, typically where
22 the agent's data enters the private backbone 6 that connects to
23 computer 1. Each border outpost computer 16 comprises a CPU
24 18, a trusted time source 17, and an input/output port 19.
25 Time source 17, which may comprise a GPS clock accurate to a
26
27
28

1 millionth of a second, is used to generate a digital time stamp
2 that is added to each data packet before it is forwarded to
3 computer 1. The GPS clocks 17 of all the border outpost
4 computers 16 are synchronized with each other to a high degree
5 of accuracy (typically one microsecond). The time stamp may be
6 placed onto the packet without the border outpost computer 16
7 having to understand the packet or have access to its contents.
8 At the computer 1 site, the time stamp is stripped off before
9 the packet is processed, and then reassociated with the data
10 after it is decrypted and parsed into a command. Computer 1
11 then sorts the messages into a queue by time order. After a
12 fixed time delay, the message that is at the front of the queue
13 is serviced by computer 1. The fixed time delay is chosen so
14 that with a high degree of certainty a message from the
15 remotest agent's 2 computer will arrive at computer 1 within
16 the fixed time delay. The purpose of the fixed time delay is
17 to allow all messages that might be the first-originated
18 message to have a chance to arrive at computer 1 before
19 execution of any messages takes place. The time stamp may be
20 encrypted using either a symmetric or assymetric cipher, to
21 prevent its modification or falsification.

22
23
24
25 Figure 10 is a deal fulfillment (flow) graph, illustrating
26 the flow in the lot instrument. The lot instrument L is the
27 portion of the traded instrument that has to be traded in a
28 round lot, typically a multiple of a million. The quoted

1 instrument Q is that portion of the instrument being traded
2 that is expressed as the lot instrument times a price. In this
3 example, agent 4(2) buys 10M Euros using U.S. dollars at an
4 exchange rate of 0.9250 from agent 4(1). Since the Euro is the
5 lot currency in this example, it has to be specified in a round
6 lot (multiple of 1 million Euros). $F(L)$, the lot size
7 (volume), is 10 million and $F(Q)$, the quoted volume, is
8 9,250,000. In this example, there are three intermediaries
9 (middlemen): agents 5(1), 5(2), and 5(3). Only credit-bridging
10 agents 5 can be middlemen. For purposes of simplification, we
11 show on Figure 10 the flow of just the lot instrument L. There
12 is also a counterflow in the quoted instrument Q, which can be
13 derived from the lot flow and the traded price. For example,
14 on the edge 3 between node 5(1) and 4(2,) 2M represents the
15 flow of 2 million Euros from agent 5(1) to agent 4(2), as well
16 as the counterflow of 1,850,000 U.S. dollars from agent 4(2) to
17 agent 5(1).

20 Figure 11, a simplified focus change diagram, illustrates
21 the sequence of screen shots appearing on the display of a
22 computer of an agent 2 who is coupled to central computer 1.
23 Agent 2 first encounters a log-in dialog box 21, then a menu
24 bar 22 where he can select from an account management dialog
25 box 23, a net exposure screen 35, a balance sheet 36, or his
26 custom limit order book 24,25. From custom limit order book
27 overview screen 24, agent 2 can navigate to one of N order book
28

1 detail screens 25, or to an activity dialog screen 27, which
2 can take the form of a bid dialog box 28, an offer dialog box
3 29, a buy dialog box 30, a sell dialog box 31, or a market
4 order screen 32. As shown in Figure 11, various of these
5 screens can segue into a bid/offer cancel dialog box 33 or a
6 confirmation dialog box 34.
7

8 Figures 12-21 illustrate most of the above screens. The
9 login screen is shown (Figure 12), followed by two shots of the
10 main desktop (Figures 13 and 14) showing the custom limit order
11 book overview window 24 and the custom limit order book detail
12 window 25. The remaining screen shots (Figs. 15-21) are of
13 dialog boxes that can be activated from either the overview
14 window 24 or detail order windows 25.
15

16 Figure 12 illustrates log-in dialog box 21. Field 41
17 allows agent 2 to type in his name, thus identifying the
18 account and trader. Field 42 is an optional challenge field,
19 provided for security purposes. An appropriate response from
20 the agent 2 to meet the challenge might include presentation of
21 a password, key, or digital certificate via a hardware token.
22 Field 43 is where agent 2 enters his password. Field 44 is
23 where agent 2 enters the address of central computer 1. In the
24 case of an Internet connection, the URL of computer 1 is
25 specified here. The data exchange between agent 2 and central
26 computer 1 is encrypted, e.g., by a SSL (Secure Socket Layer)
27
28

1 connection. Field 45 is a scrolling message log showing status
2 and notification of errors during the log-in process.

3 Figure 13 illustrates the main custom limit order book
4 screen 24. Field 51 specifies the current account. Field 52
5 is a summary of the custom limit order book for each
6 permitted traded instrument. In this sample, where the
7 instruments are pairs of currencies, the traded instruments are
8 identified by icons representing the flags of the countries
9 issuing the currencies. There are five fields 52 illustrated,
10 representing five permitted instruments. The second field
11 52 from the top (Great Britain pounds for U.S. dollars) is
12 exploded, indicating the traded instrument currently activated
13 by agent 2.
14

15
16 Field 53 displays the top (best) orders from the point of
17 view of the agent 2. Field 54 displays the best bid price for
18 any agent 2 coupled to the network 6,7. Field 55 displays the
19 last two digits ("84") of the best available bid price. Field
20 56 displays the size at the best bid price. Field 57 displays
21 agent 2's available liquidity for additional selling. Field 58
22 provides agent 2 with a mouse-clickable area (the big figure)
23 enabling the agent 2 to jump to the buy or sell dialog screen
24 30 or 31, with amounts already filled in. Field 59 is a mouse-
25 clickable numeric keypad allowing the agent 2 to create and
26 cancel orders. Field 60 gives balance sheet values showing
27 live valuations at market price and the profit that was banked
28

1 by agent 2 for a certain period of time, such as the current
2 day. Field 61 is a pop-up console allowing for the display of
3 application messages, connection failure/retry messages, and
4 broadcast messages from central computer 1. Field 62 displays
5 the time since the agent 2 has logged in to computer 1. Field
6 63 displays the best available offer; in this case, four digits
7 of the available offer are used to warn agent 2 that his best
8 available offer is far from the overall best, due to a credit
9 bottleneck. Field 64 shows this agent's orders in red. Field
10 65 shows this agent's current net position in the instrument
11 being traded. Field 66 shows a summary of this agent's offers.
12 Field 67 is a mouse-clickable area (tab 9) enabling the agent 2
13 to quickly cancel the top offer.
14

15
16 Figure 14 illustrates a custom limit order book depth
17 window 25. There are N of these windows 25 for each
18 instrument, where N is any preselected positive integer.
19 Typically, N is equal to five. The N windows 25 display the N
20 best bids and offers in order of price, and within price, in
21 order of date and time, with the oldest presented first. Field
22 71 shows bid and offer information, with the last two digits of
23 the bid and offer ("99" and "02", respectively) displayed in
24 large numerals for readability. Field 72 shows visible (to
25 that agent 2) bids and offers truncated by current credit
26 availability, individually or aggregated by price
27 (configurable). Bids and offers from this agent's account are
28

1 shown in pink. Field 73 is a mouse-clickable field allowing
2 agent 2 to navigate to screen 33 (Fig. 17). Field 74 is a set
3 of four mouse-clickable areas enabling agent 2 to open buy,
4 sell, bid, and offer dialog boxes (30, 31, 28, and 29,
5 respectively), with price and size information pre-loaded from
6 the current market.
7

8 Figure 15 illustrates net exposure monitor 35. Each entry
9 81 gives the current exposure for each account, broken down by
10 traded instrument. Field 82 ("min" and "max") shows asymmetric
11 net position limits on a per-instrument basis. Field 83
12 ("current") shows a real-time update of net position. Field 84
13 shows a graphical representation of net position.
14

15 Figure 16 illustrates balance sheet window 36. Field 91
16 shows payables and receivables, valued using the current market
17 price. Total net position and net position for each
18 counterparty 2 are given. Field 91 is organized as a tree
19 hierarchy, and allows navigation to individual balance sheet
20 transfers. Field 94 shows underlying flows; they have been
21 sent to the agent's computer in an encrypted form, and are
22 decrypted at the agent's computer. The decryption can be done
23 automatically, as long as the agent 2 is logged in to the
24 network 6,7. In field 94, one line represents each trade this
25 agent 2 has made, or each trade for which this agent 2 was an
26 intermediary 5. All values are live. This currency-based
27
28

1 balance sheet 36 is capable of handling triangular instrument
2 swaps.

3 Figure 17 illustrates the open order overview and
4 management window 33. Field 101 shows orders (bids and offers)
5 currently placed by that agent summarized by traded instrument.
6 Field 102 shows individual orders. Field 103 is a mouse-
7 clickable area enabling the agent 2 to remove the order from
8 the agent's custom limit order book 24,25. All values are
9 updated immediately if their value has changed. In screen 33,
10 an update procedure can be implemented in which the first offer
11 is not cancelled until a new offer is posted. This is
12 sometimes referred to as OCO (one cancels the other). In any
13 event, it is never possible for an agent 2 to cancel an order
14 after it has been taken by a counterparty 2.
15

16 Figure 18 illustrates bid creation dialog box 28. Field
17 111 is a group of icons, typically in various colors to provide
18 visual context to reduce errors. Note that the word "Bid" is
19 highlighted. Field 112 comprises three mouse-clickable areas
20 allowing for quick up or down adjustment of price and direct
21 entry of price, respectively, with initial value taken from the
22 current market. Field 113 comprises three mouse-clickable
23 areas allowing for quick up or down adjustment of size, and
24 direct entry of size, with initial value configurable based
25 upon the desires of the particular agent 2. Field 114 is a
26 mouse-clickable area allowing the agent 2 to submit the bid,
27
28

1 and has an optional confirmation dialog box associated
2 therewith. An agent 2 can post his bid for just a short period
3 of time and then withdraw it. He 2 can post multiple bids at
4 multiple prices. When a counterparty 2 takes part or all of
5 his bid, computer 1 recalculates the trading limits. Agent 2
6 can make his bid limited to "only if it is available now" or as
7 an offer to buy.
8

9 Figure 19 illustrates offer creation dialog box 29. Field
10 121 comprises a set of icons, typically colored to provide
11 visual context to reduce errors. Note that the word "Offer" is
12 highlighted. Field 122 comprises three mouse-clickable areas
13 allowing agent 2 to quickly achieve up or down adjustment of
14 price and direct entry of price, with initial value taken from
15 the current market. Field 123 comprises three mouse-clickable
16 areas providing a quick means for agent 2 to achieve up or down
17 adjustment of size and direct entry of size, with initial value
18 configurable on a per user 2 basis. Field 124 is a mouse-
19 clickable area allowing agent 2 to post the offer, and has an
20 optional confirmation dialog box associated therewith.
21
22

23 Figure 20 illustrates buy (immediate execution bid) dialog
24 box 30. Field 131 comprises a set of icons, typically colored
25 to provide visual context to reduce errors. Note that the word
26 "Buy" is highlighted. Field 132 comprises three mouse-
27 clickable areas, providing a quick means for up or down
28 adjustment of price and direct entry of price, with initial

1 value taken from the current market. Field 133 is a mouse-
2 clickable button allowing for a partial execution of a trade.
3 This allows agent 2 to buy either as much of the size as
4 possible, or nothing if he cannot buy the entire size. Field
5 134 comprises three mouse-clickable areas providing a quick
6 means for up or down adjustment of size and direct entry of
7 size, with initial value configurable on a per user 2 basis.
8 Field 135 is a mouse-clickable area allowing agent 2 to execute
9 the buy, and has an optional confirmation dialog box associated
10 therewith.
11

12 Figure 21 illustrates sell (immediate execution offer)
13 dialog box 31. Field 141 is a set of icons, typically colored
14 to provide visual context to reduce errors. Note that the word
15 "Sell" is highlighted. Field 142 comprises three mouse-
16 clickable areas providing a quick means for agent 2 to achieve
17 up or down adjustment of price and direct entry of price, with
18 initial value taken from the current market. Field 143 is a
19 mouse-clickable area allowing partial execution. This allows
20 agent 2 the choice of the sell being either to fill as much of
21 the size as possible, or to not sell if he 2 cannot sell the
22 entire size. Field 144 comprises three mouse-clickable areas
23 providing for a quick means for up or down adjustment of size
24 and direct entry of size, with initial value configurable on a
25 per user 2 basis. Field 145 is a mouse-clickable area allowing
26
27
28

1 the sell to be executed, and has an optional confirmation
2 dialog box associated therewith.

3 Figure 22 is a flow diagram illustrating the method steps
4 by which computer 1 computes a custom limit order book 24,25
5 for a single agent 2 for a single traded instrument. Even
6 intermediate agents 5 get a custom limit order book 24, 25.
7 For the left hand side of Fig. 22, source S is that node 2 for
8 which this custom limit order book is being prepared; and sink
9 T is that node 2 that has posted the bid. For the right hand
10 side of Figure 22, source S is that node 2 that posted the
11 offer; and sink T is that node 2 for which this custom limit
12 order book is being prepared. "Source" and "sink" are standard
13 network terminologies; see, e.g., the Ahuja reference
14 previously cited. These concepts are used internally by
15 computer 1, but are not disclosed to all agents 2 for reasons
16 of preserving the desired anonymity. For example, the actual
17 poster 2 of the offer does not appear on the screen of the
18 counterparty 2.
19
20

21 The method starts at step 151. In step 152, computer 1
22 asks whether there have been any trades made since the last
23 multi-hop credit computation. This is meant to avoid
24 unnecessary computation. If the answer to the question is
25 "yes", then step 153 is executed. At step 153, multi-hop
26 credit limits are computed, as illustrated in Fig. 23. If the
27 answer to the question raised in step 152 is "no", step 154 is
28

1 executed. At step 154, the bid side of the book is cleared,
2 i.e., variable B becomes the null set; the offer side of the
3 book is cleared, i.e., variable A becomes the null set; and the
4 credit used (U as a function of S and T) is cleared. In this
5 context, "used" applies only for this particular custom limit
6 order book 24,25 for this particular agent 2. Step 155 is then
7 executed, where it is asked whether enough bids have been
8 found. "Enough" is a pre-established limit, e.g., five, and
9 corresponds to N as discussed above in conjunction with custom
10 limit order book detail window 25. N may be infinity, in which
11 case the method always proceeds from step 155 to step 156. If
12 enough bids have been found, the method proceeds to step 161.
13 If enough bids have not been found, the method proceeds to step
14 156, where it is asked whether there are more unprocessed bids,
15 i.e., if the number of bids that have been processed is less
16 than the pre-established limit. If the answer is "no", step
17 161 is executed; otherwise, the method proceeds to step 157,
18 where the highest priced oldest unprocessed bid is fetched.
19 The hierarchy is according to highest bid. If there is a tie
20 as to two or more highest bids, then the bids are ordered by
21 time. It is forced that there not be a time-tie at this point;
22 time collisions have already been resolved by locking using
23 sequence numbers.

24
25 Step 158 is then executed. X is defined as the flow limit
26 (trading limit) between S and T minus the credit U between S

1 and T that has already been used up. Y is then set to be the
2 minimum of X and the bid size. In other words, Y is what we
3 have to work with. Step 159 is executed, where it is asked
4 whether Y is greater than 0. If not, the method cycles back to
5 step 155. If "yes", step 160 is executed. In step 160, the
6 set of bids B is augmented by the current bid we are working
7 with from step 157. Also in step 160, the credit used U is
8 augmented by Y.
9
10 At step 161, it is asked whether enough offers have been
11 found. Again, "enough" is a pre-established limit e.g., five,
12 corresponding to N as before. If the answer to this is "yes",
13 the method stops at step 167. If the answer is "no", step 162
14 is executed. At step 162, it is asked whether there are more
15 unprocessed offers. If not, the method ends at step 167. If
16 "yes", step 163 is executed, where the lowest priced, oldest
17 unprocessed offer is fetched. Then, step 164 is executed,
18 where X is set to be the trading limit between S and T minus
19 the unused credit U. Y is then set to be the minimum of X and
20 the offer size. Step 165 is then executed. At step 165, it is
21 asked whether Y is greater than 0. If not, control is passed
22 back to step 161. If "yes", step 166 is executed, where the
23 current offer price being worked on from box 163 is added to
24 the set of offers A; and the credit used U is augmented by Y.
25 Control then passes back to step 161.
26
27
28

1 Figure 23 illustrates how computer 1 calculates multi-hop
2 trading limits for each pair of agents 2 for a single traded
3 instrument L:Q, i.e., how computer 1 performs step 153 on
4 Figure 22. This is akin to compiling a table like Table 1
5 shown above. This procedure starts at step 171. At step 172,
6 a directed graph is computed for the traded instrument L:Q, in
7 which the arrow corresponds to the direction of flow of the lot
8 instrument L. Individual trading limits are introduced at this
9 point. Step 172 is the subject of Figure 24. At step 173, an
10 arbitrary network node 2 is selected to be the first node
11 worked upon by the process and is given the designation source
12 S. At step 174, sink T is also set to be said first network
13 node 2. At step 175, it is asked whether S is equal to T. If
14 so (which, of course, is the case initially), the procedure
15 moves to step 176, where the maximum flow limit between S and T
16 is set to be infinity. This is simply another way of saying
17 that an agent 2 is allowed to have an infinite flow with
18 himself 2. Then, at step 182, it is asked whether T is the
19 last network node that needs to be processed. If "yes",
20 control is passed to step 184; if "no", control is passed to
21 step 183, where T is advanced to the next network node; and
22 control is passed back to step 175. "Next" can be anything,
23 because the order of processing is of no import.

27 If S is found not to be equal to T at step 175, control is
28 passed to step 177, which disables edges 3 where the edge

1 origin 2 is not a credit bridge 5 and the edge origin 2 is not
2 equal to S. An edge 3 may be disabled internally by adjusting
3 its maximum capacity to 0 or by removing it from the set of
4 edges 3 that comprise the graph. The "edge origin" is that
5 node 2 from which the lot instrument L flows. Steps 177 and
6 178 eliminate agents 2 who have not agreed in advance to be
7 intermediaries, i.e., "credit bridges". An intermediary
8 (credit bridge) is an agent 5 that allows two other agents 2 to
9 do back-to-back trades through the intermediary agent 5. Step
10 178 disables edges 3 where the edge destination 2 is not a
11 credit bridge 5 and the edge destination 2 is not equal to T.
12 An "edge destination" is a node 2 that receives the flow of the
13 lot instrument L.
14

15
16 At step 179, the maximal flow from S to T is computed
17 using a maximal flow algorithm such as one of the algorithms
18 disclosed in Chapter 7 of the Ahuja reference previously cited.
19 At step 180, the multi-hop credit limit between S and T,
20 $LIM(S,T)$, is set to be equal to the maximum flow obtained from
21 step 179. At step 181, the edges 3 that were disabled in steps
22 177 and 178 are re-enabled. Step 184 asks whether S is the
23 last network node to be processed. If "yes", the procedure
24 concludes at step 186. If "no", the process moves to step 185,
25 where S is advanced to the next network node. Again, "next" is
26 arbitrary and simply refers to any other unprocessed node 2.
27 After step 185, the method re-executes steps 174.
28

1 Figure 24 illustrates how computer 1 calculates a directed
2 graph for the traded instrument L:Q, i.e., how computer 1
3 performs step 172 of Figure 23. This is akin to producing a
4 graph such as that shown in Fig. 5, with arrows as in Fig. 10.
5 The operation commences at step 191. At step 192, the edge 3
6 set G is nulled out. At step 193, computer 1 searches its
7 records for any account A that it has not yet processed. The
8 order of selection of unprocessed accounts is irrelevant.
9 Account A is any pre-existing trading (credit) relationship
10 between two neighboring agents 2 that has been previously
11 conveyed to the operator of computer 1 in writing in
12 conjunction with these agents 2 subscribing to the trading
13 system operated by the operator of computer 1.
14
15 Step 194 asks whether there is any such unprocessed
16 account A. If "not", this process stops at step 198. If there
17 is an unprocessed account A, the process executes step 195,
18 where the minimum and maximum excursions for account A are
19 calculated. Step 195 is the subject of Figure 25. These
20 minimum and maximum excursions are defined in terms of the lot
21 instrument L, and are calculated from one or more of eight
22 possible ways of specifying input credit limits. The maximum
23 and minimum excursions are excursions from current position.
24 The input credit limits are specified as part of each account
25 A. In step 196, the set of edges G is augmented with an edge 3
26 from A's lender 2 to A's borrower 2, with the capacity of the
27
28

1 edge 3 being set to the maximum excursion. L is the lot
2 instrument and Q is the quoted instrument. In step 197, the
3 set of edges G is augmented with an edge 3 from A's borrower 2
4 to A's lender 2, with the capacity of the edge 3 being set to
5 the negative of the minimum excursion. The process then re-
6 executes step 193.

8 Figure 25 shows how computer 1 calculates the minimum and
9 maximum excursions for a single account A and a single traded
10 instrument L:Q, i.e., how computer 1 executes step 195 of
11 Figure 25. This computation takes into account up to eight
12 different ways a guaranteeing agent 5 may specify input credit
13 limits in an account A. The operation commences at step 201.
14 At step 202, the maximum excursion is set to be infinity and
15 the minimum excursion is set to be minus infinity, because at
16 this point there are no trading limits.

18 Step 203 asks whether position limits have been defined
19 for the lot instrument. If yes, step 204 is executed. At step
20 204, the lot instrument position limits' effects on the
21 maximum and minimum excursions are calculated. This is the
22 subject of Figure 26. At step 205, it is asked whether volume
23 limits have been specified for the lot instrument. If so, step
24 206 is executed. At step 206, the lot limit volume limits'
25 effects on the maximum and minimum excursions are calculated.
26 This is the subject of Figure 28. At step 207, it is asked
27 whether position limits have been specified for the quoted
28

1 instrument. If so, step 208 is executed. At step 208, the
2 quoted instrument position limits' effects on the maximum and
3 minimum excursions are calculated. This is the subject of
4 Figure 27. At step 209, it is asked whether volume limits have
5 been specified for the quoted instrument. If so, step 210 is
6 executed. At step 210, the quoted instrument volume limits'
7 effects on the maximum and minimum excursions are calculated.
8 This is the subject of Figure 29. At step 211, it is asked
9 whether notional position limits have been specified. If so,
10 step 212 is executed. At step 212, the notional position
11 limits' effects on the maximum and minimum excursions are
12 calculated. This is the subject of Figure 30. At step 213, it
13 is asked whether notional volume limits have been specified.
14 If so, step 214 is executed. At step 214, the notional volume
15 limits' effects on the maximum and minimum excursions are
16 calculated. This is the subject of Figure 31. At step 215, it
17 is asked whether position limits have been specified for the
18 traded instrument L:Q. If so, step 216 is executed. At step
19 216, the traded instrument L:Q position limits' effects on the
20 maximum and minimum excursions are calculated. This is the
21 subject of Figure 32. At step 217, it is asked whether volume
22 limits have been specified for the traded instrument L:Q. If
23 so, step 218 is executed. At step 218, the traded instrument
24 L:Q volume limits' effects on the maximum and minimum
25 excursions are calculated. This is the subject of Figure 33.

1 Then step 219 is executed, where the maximum excursion is
2 set to be equal to the maximum of 0 and the current value of
3 the maximum excursion. This is done because we don't want to
4 have a negative maximum excursion. At step 220, the minimum
5 excursion is set to be the minimum of 0 and the current value
6 of the minimum excursion. This is done because we do not want
7 to have a positive minimum excursion. Then, the method ends at
8 step 221.
9

10 It is important to note that the order of taking into
11 account the effects of the eight types of specified input
12 credit limits is irrelevant, because each of the eight can only
13 constrict an excursion more, not expand it. Therefore, the
14 ultimate limit is the most restrictive one. All of the eight
15 trading limits described herein are recalculated after each
16 trade affecting that limit.
17

18 As used herein, a "trading limit" is something calculated
19 by computer 1, and a "credit limit" is something specified by a
20 guaranteeing agent 5.
21

22 Conventional mathematical shortcuts can be used to speed
23 the calculations without necessarily having to repeat all the
24 method steps in all but the first time a particular method is
25 executed. All of the steps of Fig. 25 get executed the first
26 time a method shown in Figures 26 through 33 is executed.
27

28 Figure 26 shows how computer 1 calculates the position
limit for the lot instrument, i.e., how computer 1 performs

1 step 204 of Figure 25. A position limit is a net limit in the
2 instrument being traded. The method starts at step 231. At
3 step 232, computer 1 retrieves the specified input maximum
4 position credit limit for instrument L, $PMAX(L)$, and the
5 specified input minimum position credit limit for instrument L,
6 $PMIN(L)$. Normally, $PMIN(L)$ is the negative of $PMAX(L)$, but
7 that doesn't necessarily have to be true. Also in step 232,
8 the net position, POS, is zeroed out.

10 In step 233, computer 1 looks for another unsettled flow
11 of instrument L in account A. "Another" is arbitrary. At step
12 234, it is asked whether such another unsettled flow exists.
13 If not, control passes to step 238. If the answer is "yes",
14 step 235 is executed, wherein it is asked whether the flow is
15 to account A's borrower 2. A "flow" is a transfer of a single
16 instrument along a single edge 3. This is the same as asking
17 whether the flow is to other than a guaranteeing agent 5,
18 because the lender is the guaranteeing agent 5. If the answer
19 is yes, step 236 is executed, during which POS is augmented by
20 the flow amount, and control passes back to step 233. This
21 inner loop 233-236 constitutes calculation of the net position,
22 and is performed for each Q matching that L.

25 If the answer to the question posed in step 235 is "no",
26 step 237 is executed, wherein POS is decremented by the flow
27 amount, and control is passed back to step 233. At step 238, X
28 is set to be equal to $PMAX(L)$ minus POS, and Y is set equal to

1 PMIN(L) minus POS. X is the maximum excursion from this
2 flowchart and Y is the minimum excursion from this flowchart.
3 At step 239, the maximum excursion for the traded instrument
4 L:Q is set to be equal to the minimum of the current value of
5 this maximum excursion and X; and the minimum excursion for the
6 traded instrument L:Q is set to be equal to the maximum of the
7 minimum of the current value of the minimum excursion and Y.
8 In other words, the set of maximum and minimum excursions is
9 updated based upon the results of this flowchart. The method
10 ends at step 240.
11

12 Figure 27 illustrates how computer 1 calculates the
13 position limit for the quoted instrument, i.e., how computer 1
14 performs step 208 of Figure 25. Other than the fact that Q is
15 substituted for L, the method described in Figure 27 is
16 identical to that described in Figure 26, with one exception:
17 in step 259 (analogous to step 239 of Figure 26), we convert
18 from the quoted instrument to the lot instrument, because we
19 want everything expressed in terms of the lot instrument once
20 we get to the higher level flowchart (Fig. 25). Therefore, in
21 step 259, X and Y are each multiplied by a "fixed rate Q:L"
22 (exchange rate). This exchange rate is fixed for a certain
23 period of time, e.g., one hour or one day, and may be different
24 for different accounts at the same moment in time.
25
26

27 Figure 28 illustrates how computer 1 calculates the volume
28 limit for the lot instrument, i.e., how computer 1 performs

1 step 206 of Figure 25. A volume limit is a gross limit in the
2 instrument being traded. The method starts at step 271. In
3 step 272, computer 1 retrieves the specified input maximum
4 permissible volume credit limit for instrument L, $V_{MAX}(L)$; and
5 clears a variable field VOL representing total volume. In step
6 273, computer 1 looks for another unsettled flow of instrument
7 L in account A. "Another" is arbitrary. At step 274, it is
8 asked whether such another unsettled flow has been found. If
9 "yes", at step 275, VOL is augmented with the flow amount. It
10 doesn't matter whether the flow is in or out to a particular
11 node 2; it counts towards the volume limit the same in each
12 case.
13

14
15 Control is then passed back to step 273. If the answer
16 posed in step 274 is "no", step 276 is executed, wherein X is
17 set equal to $V_{MAX}(L)$ minus VOL, and Y is set equal to minus X,
18 because of the definition of "volume". Again, X and Y are the
19 partial limits as calculated by this particular flowchart.
20 Then in step 277, the maximum excursion is set equal to the
21 minimum of the previous value of the maximum excursion and X;
22 in the minimum excursion is set equal to the maximum of the
23 previous value of the minimum excursion and minus X. In other
24 words, the overall excursions are updated based upon the
25 results of this flowchart. The method then ends at step 278.
26

27 Figure 29 illustrates how computer 1 calculates the volume
28 limit for the quoted instrument, i.e., how computer 1 performs

1 step 210 of Figure 25. Other than the fact that Q is
2 substituted for L, the method steps of Figure 29 are identical
3 to those of Figure 28, with one exception: in step 287
4 (analogous to step 277 of Figure 28), X and minus X are each
5 multiplied by "fixed rate Q:L" for the same reason that this
6 factor was introduced in Figure 27.
7

8 Figure 30 illustrates how computer 1 calculates the
9 notional position limit, i.e., how computer 1 performs step 212
10 of Figure 25. The notional position limit protects the
11 guaranteeing agent 5 against rate excursions aggregated over
12 the positions in all of the instruments. "Notional" means we
13 are changing the notation; the concept implies that there is a
14 conversion from one instrument to another, and that the
15 conversion is done at a certain rate that has been agreed upon.
16 The rate is set periodically, e.g., daily. This conversion
17 from one instrument to another is used to convert all values
18 into a single currency for the purpose of aggregation into a
19 single value.
20

21 The method commences at step 291. At step 292, computer 1
22 retrieves the maximum notional position credit limit P_{MAXN},
23 where N is the notional instrument, i.e., the instrument in
24 which the limit is presented. In step 292, the notional
25 position, N_{POS}, is also zeroed out. In step 293, computer 1
26 looks for another instrument C with flows in account A. C is
27 an index designating the instrument for which we are executing
28

1 the loop 293-301. The order of selecting the instruments is
2 immaterial. Step 294 asks whether such another instrument C
3 has been found. If not, control passes to step 302. If the
4 answer is yes, step 295 is executed, wherein the instrument
5 position, POS(C), is zeroed out. At step 296, computer 1 looks
6 for another unsettled flow of instrument C in account A.
7

8 Step 297 asks whether such another unsettled flow has been
9 found. If not, control passes to step 301. If the answer is
10 "yes", step 298 is executed, where it is asked whether the flow
11 is to account A's borrower 2. If "yes", POS(C) is augmented
12 with the flow amount at step 299. If not, POS(C) is
13 decremented by the flow amount at step 300. In either case,
14 control is returned to step 296. Note that the inner loop 296-
15 300 is analogous to the loops in Figures 26 and 27. At step
16 301, NPOS is augmented by the absolute value of POS(C)
17 multiplied by "fixed rate C:N", which converts to the notional
18 instrument. The absolute value of POS(C) is used, because a
19 negative position presents the same risk to the guaranteeing
20 agent 5 as a positive position.
21

22 Before we describe step 302, let us define A and B, as
23 those terms are used in step 302. Note that "A" in step 302 is
24 not the same as "account A". A is the position of L, POS(L),
25 multiplied by "fixed rate L:N", which converts this position to
26 the notional instrument. B is the position of Q, POS(Q),
27 multiplied by "fixed rate Q:N", which converts this to the
28

1 notional instrument. The positions of L and Q are as
2 calculated in the above loop 294-301; if L and Q were not
3 subject to these notional limits, then A and B would be 0.

4 In step 302, computer 1 finds the minimum and maximum
5 roots of $F(X)$, where $F(X)$ is defined in step 302. The term
6 "root" is that of conventional mathematical literature, i.e., a
7 value of X that makes $F(X)$ equal to 0. Let us define E to be
8 equal to the absolute value of A plus B, plus NPOS, minus the
9 absolute value of A, minus the absolute value of B, minus
10 PMAXN. If E is greater than 0, then there are no roots. In
11 that eventuality, we set the maximum excursion of the traded
12 instrument L:Q, $MAXEXC(L,Q)$, and the minimum excursion of the
13 traded instrument L:Q, $MINEXC(L,Q)$, to be equal to 0. If E is
14 less than or equal to 0, the maximum root is the maximum of
15 minus A and B, minus $E/2$; and the minimum root is the minimum
16 of minus A and B, plus $E/2$. Now we are ready to go to step
17 303.

18 At step 303, the maximum excursion of the traded
19 instrument L:Q is set equal to the minimum of the previous
20 version of the maximum excursion of the traded instrument L:Q
21 and the maximum root multiplied by "fixed rate N:L", which
22 converts it to the lot instrument. Similarly, the minimum
23 excursion of the traded instrument L:Q is set equal to the
24 maximum of the previous version of the minimum excursion of the
25 traded instrument L:Q and the minimum root multiplied by the

1 same conversion factor, "fixed rate N:L". The method
2 terminates at step 304.

3 Figure 31 illustrates how computer 1 calculates the
4 notional volume limit, i.e., how computer 1 performs step 214
5 of Figure 25. The method starts at step 311. At step 312,
6 computer 1 retrieves the specified input maximum notional
7 volume credit limit, VMAXN. This is a limit across all
8 instruments in the account. At step 312, the total volume,
9 VOL, is also zeroed out. At step 313, computer 1 looks for
10 another unsettled flow of any instrument C in account A.
11 Again, "another" is arbitrary. At step 314, it is asked
12 whether such another unsettled flow has been found. If "yes",
13 step 315 is executed; if "no", step 316 is executed.

14 Let R be the conversion factor "fixed rate C:N", where C
15 is the instrument that we are looping through currently. Then,
16 step 315 sets VOL to be the previous VOL plus the quantity R
17 times the flow amount. Step 313 is then entered into. At step
18 316, X is set equal to VMAXN minus VOL. Again, X is the limit
19 from just this flowchart. At step 317, the maximum excursion
20 of the traded instrument L:Q is set equal to the minimum of the
21 previous value of the maximum excursion of the traded
22 instrument L:Q and X times "fixed rate N:L", i.e., we are
23 converting from the notional instrument to the lot instrument.
24 Similarly, the minimum excursion of the traded instrument L:Q
25 is set equal to the maximum of the previous version of the
26
27
28

1 minimum excursion of the traded instrument L:Q and minus X
2 times the same conversion factor. The method ends at step 318.

3 Figure 32 illustrates how computer 1 calculates an
4 instrument position limit, i.e., how computer 1 performs step
5 216 of Figure 25. This type of position limit differs from the
6 previous position limit flowcharts (Figures 26 and 27) in that
7 the guaranteeing agent 5 is specifying that another agent 2
8 cannot trade any more than jL for Q , rather than the other
9 agent 2 can trade no more than jL or jQ . This type of input
10 credit limit is not as common as the ones described in Figures
11 26 and 27. If no agent 2 has specified this type of input
12 credit limit, this flowchart 33 does not have to be executed.
13 (Similarly, if no agent 2 has specified a certain other type of
14 input credit limit, the flowchart corresponding to that credit
15 limit does not have to be executed.) Both the L and the Q have
16 to match in order for this flowchart 33 to be executed, unlike
17 the flowcharts described in Figures 26 and 27.

18 The method starts at step 321. At step 322, computer 1
19 looks up the specified maximum position credit limit for the
20 traded instrument L:Q, $PMAX(L,Q)$, and the specified minimum
21 position credit limit for the traded instrument L:Q, $PMIN(L,Q)$.
22 In step 322, the total position, POS , is also zeroed out. In
23 step 323, computer 1 looks for another unsettled flow pair with
24 lot instrument L , quoted instrument Q , and account A . Again,
25 "another" is arbitrary. At step 324, it is asked whether such
26
27
28

1 another unsettled flow pair has been found. If "no", control
2 passes to step 328. If "yes", control passes to step 325,
3 where it is asked whether the lot instrument flows to account
4 A's borrower 2. In other words, the calculation is done in
5 terms of the lot instrument to begin with, so that we do not
6 have to convert to the lot instrument at the end of the
7 calculation. If the answer to this question is "yes", step 326
8 is executed, where POS is incremented with the lot instrument
9 flow amount. Control then passes to step 323. If the answer
10 to the question posed in step 325 is "no", step 327 is
11 executed, where POS is decremented by the lot instrument flow
12 amount. Again, control then passes to step 323. At step 328,
13 X is set equal to $PMAX(L,Q)$ minus POS, and Y is set equal to
14 $PMIN(L,Q)$ minus POS. At step 329, the maximum excursion of the
15 traded instrument L:Q is set equal to the minimum of the
16 previous version of the maximum excursion of the traded
17 instrument L:Q and X; and the minimum excursion of the traded
18 instrument L:Q is set equal to the maximum of the previous
19 value of the minimum excursion of the traded instrument L:Q and
20 Y. The method ends at step 330.

21
22
23
24 Figure 33 illustrates how computer 1 calculates a traded
25 instrument volume limit, i.e., how computer 1 performs step 218
26 of Figure 25. This method is similar to the method described
27 in Figures 28 and 29, except the limit is on the volume traded
28 of L for Q, not a limit on the volume of L or Q individually.

1 The method starts at step 341. In step 342, computer 1
2 retrieves the specified maximum volume input credit limit for
3 the traded instrument L:Q, $V_{MAX}(L,Q)$. Also in step 342, the
4 total volume VOL is zeroed out. In step 343, computer 1 looks
5 for another unsettled flow pair with lot instrument L, quoted
6 instrument Q, and account A. Again, "another" is arbitrary.
7
8 At step 344, it is asked whether such another unsettled
9 flow pair has been found. If "no", control passes to step 346.
10 If "yes", control passes to step 345, where VOL is augmented by
11 the lot instrument flow amount. The calculation is done in the
12 lot instrument, so that we do not have to convert to the lot
13 instrument at the end; and it makes the calculation more
14 stable, because we don't have to worry about fluctuating rates.
15 Control is then passed to step 343. At step 346, X is set
16 equal to $V_{MAX}(L,Q)$ minus VOL. At step 347, the maximum
17 excursion of the traded instrument L:Q is set equal to the
18 minimum of the previous version of the maximum excursion of the
19 traded instrument L:Q and X. Similarly, the minimum excursion
20 of the traded instrument L:Q is set equal to the maximum of the
21 previous value of the minimum excursion of the traded
22 instrument L:Q and minus X. The method stops at step 348.
23
24 Figure 34 illustrates the reporting by computer 1 of
25 single-hop trades. This method is executed after a match has
26 been made, i.e., after a bid or offer has been taken by a
27 counterparty 2. The method of Figure 34 can be done either in
28

1 real time or in batch mode (i.e., combined with the reporting
2 of other trades). In Fig. 34, L is the lot instrument, Q is
3 the quoted instrument, B is the agent 2 who is buying L, S is
4 the agent 2 who is selling L, P is the trade price, F_L is the
5 amount of L bought and sold, F_Q is P times F_L , i.e., the
6 counter-amount in terms of instrument Q, and T is the
7 settlement date and time.

9 The method starts at step 351. At step 352, central
10 computer 1 issues an electronic deal ticket 353 to an auditor.
11 The auditor is a trusted third party, e.g., an accounting firm.
12 Ticket 353 has a plaintext portion and an encrypted portion.
13 The plaintext gives the ticket ID, and the time and date that
14 the ticket 353 is generated. The encrypted portion states that
15 agent B bought F_L for F_Q from agent S for settlement at T.
16 Deal ticket 353 is digitally signed by central computer 1 for
17 authentication purposes, and encrypted by central computer 1 in
18 a way that the auditor can decrypt the message but central
19 computer 1 cannot decrypt the message. This is done for
20 reasons of privacy, and can be accomplished by computer 1
21 encrypting the message using the public key of the auditor in a
22 scheme using public key cryptography.

25 At step 354, computer 1 issues an "in" flow ticket 355 to
26 buyer B and to the auditor. Flow ticket 355 contains a
27 plaintext portion and an encrypted portion. The plaintext
28 gives the ticket ID, the time and date the ticket 355 is

1 generated, and the name of agent B. The encrypted portion
2 states that you, agent B, bought F_L for F_0 from counterparty S
3 for settlement at T. Ticket 355 is digitally signed by
4 computer 1 and encrypted in such a way that it may be decrypted
5 only by agent B and by the auditor, not by computer 1. Two
6 different encryptions are done, one for agent B and one for the
7 auditor.
8

9 At step 356, computer 1 issues an "out" flow ticket 357 to
10 seller S and to the auditor. Out flow ticket 357 contains a
11 plaintext portion and an encrypted portion. The plaintext
12 gives the ticket ID, the time and date of issuance, and the
13 name of agent S. The encrypted portion states that you, agent
14 S, sold F_L for F_0 to counterparty B for settlement at T.
15 Ticket 357 is digitally signed by computer 1 and encrypted only
16 to agent S and to the auditor, not to computer 1. Two
17 different encryptions are used, one to agent S and one to the
18 auditor.
19

20 Tickets 353, 355, and 357 can include the digital identity
21 of the individual within the agent 2 whose smartcard was
22 plugged into the agent's computer when the transaction was
23 made. The method ends at step 358.
24

25 Figure 35 illustrates how computer 1 electronically
26 reports a multi-hop deal. This method is performed after the
27 match has been made and can be done either in real time or in
28 batch mode. Agents B and S do not know each other, as they

1 know the identities of just their nearest neighboring agents 2.
2 The notation for this flowchart is identical to that for Figure
3 35, except that B is the ultimate buyer of L and S is the
4 ultimate seller of L.

5 The method begins at step 361. At step 362, computer 1
6 issues deal ticket 363 to the auditor. Ticket 363 contains a
7 plaintext portion and an encrypted portion. Ticket 363 is
8 digitally signed by computer 1 and encrypted only to the
9 auditor. The encrypted portion states that agent B bought F_L
10 for F_Q from agent S for settlement at T, and that the deal was
11 fulfilled by multiple direct trades in D, the directed deal
12 fulfillment graph, i.e., the type of graph that is illustrated
13 in Figure 10. In other words, the auditor knows every agent 2
14 in the chain.
15

16 At step 364, computer 1 looks for the next unprocessed
17 agent V in graph D. Again, "next" is arbitrary. At step 365,
18 it is asked whether such an unprocessed agent V has been found.
19 If not, the method stops at step 366. If the answer is "yes",
20 node loop 370 is entered into. For agent V, this node loop
21 examines the set E_V of directed edges 3 in D which have agent V
22 as either a source or destination. Each edge 3 has an amount F
23 that is greater than zero and less than or equal to F_L . Note
24 that this verification process is for illustration only; there
25 would not be a match if these constraints were not satisfied.
26 At step 367, it is asked whether agent V is the ultimate buyer
27
28

1 B of the deal. If "no", control is passed to step 368. If
2 "yes", control is passed to step 371.

3 At step 368, it is asked whether agent V is the ultimate
4 seller S of the deal. If "no", control is passed to step 369.
5 If "yes", control is passed to step 372. At step 369, computer
6 1 concludes that agent V is an incidental participant in the
7 deal, i.e., a middleman 5. Control is then passed to step 373,
8 which verifies that the sum of the edge 3 amounts having agent
9 V as a source equals the sum of the edge amounts 3 having agent
10 V as a destination. Sums are used because that agent 5 could
11 have several edges 3 in and out. Therefore, it is known that
12 agent V has no net market position change. Control is then
13 passed to step 376. At step 372, it is verified that agent V
14 is the source node 2 (as opposed to the destination node) of
15 all edges 3 in E_v . In step 375, it is verified that edge 3
16 amounts in E_v sum to F_L , the net amount sold. Control is then
17 passed to step 376.

20 In step 371, it is verified that agent V is the
21 destination node 2 (as opposed to the source node) of all edges
22 3 in E_v . At step 374, it is verified that edge 3 amounts in E_v
23 sum to F_L , the net amount bought. Control is then passed to
24 step 376, where computer 1 looks for the next unprocessed edge
25 in E_v corresponding to account A. Steps 376-382 constitute an
26 edge loop. Account A is any account held by or extended to
27 counterparty X. Counterparty X is the counterparty 2 to agent
28

1 V for that edge 3. The edge 3 has to have some amount F , where
2 F is greater than 0 and less than or equal to F_L , and an
3 implicit counter-amount F times P ; otherwise, there would be no
4 way to clear the trade. Again, "next" in step 376 is
5 arbitrary. Control is then passed to step 382.
6

7 At step 382, it is asked whether such a next unprocessed
8 edge 3 has been found. If not, control is passed to step 364.
9 If "yes", control is passed to step 381, where it is asked
10 whether agent V is the destination node 2 for this edge 3. If
11 "yes", then step 380 is executed. If "no", then by definition,
12 agent V is the source node 2 for this edge 3, and step 379 is
13 executed. Control is passed to step 376 after either of step
14 379 or 380 is executed.
15

16 At step 380, computer 1 reports an "in" flow ticket 377 to
17 agent V , because the lot currency is flowing in to agent V .
18 Flow ticket 377 contains a plaintext portion and an encrypted
19 portion. The plaintext includes the ticket ID, the time and
20 date of issuance, and the name of agent V . The encrypted
21 portion states that you, agent V , bought F of L for F times P
22 of Q from counterparty X for settlement at T . In this case,
23 counterparty X is just the immediate neighbor 2 to agent V ,
24 preserving anonymity. Ticket 377 is digitally signed by
25 computer 1 and encrypted by computer 1 only to agent V and to
26 the auditor, not to computer 1. Two encryptions are performed,
27 one to agent V and one to the auditor.
28

1 At step 379, computer 1 generates an "out" flow ticket 378
2 to agent V. Ticket 378 contains a plaintext portion and an
3 encrypted portion. The plaintext includes the ticket ID, the
4 time and date of issuance, and the name of agent V. The
5 encrypted portion states that you, agent V, sold F of L for F
6 times P of Q to counterparty X for settlement at T. Again,
7 counterparty X is just the immediate neighbor 2 to agent V,
8 preserving anonymity. Flow ticket 378 is digitally signed by
9 computer 1 and encrypted by computer 1 only to agent V and to
10 the auditor, not to computer 1. Two encryptions are performed,
11 one to agent V and one to the auditor.
12

13 Tickets 363, 377, and 378 can include the digital identity
14 of the individual within agent 2 whose smartcard was plugged
15 into the agent's terminal when the transaction was made.
16

17 The above description is included to illustrate the
18 operation of the preferred embodiments and is not meant to
19 limit the scope of the invention. The scope of the invention
20 is to be limited only by the following claims. From the above
21 discussion, many variations will be apparent to one skilled in
22 the art that would yet be encompassed by the spirit and scope
23 of the present invention.
24

25 What is claimed is:
26
27
28